Fermilab FERMILAB-Conf-01/095-E CDF & D0 June 2001

MEASUREMENT OF THE W AND TOP MASS AT THE TEVATRON: RESULTS AND PERSPECTIVES

ANDREA CASTRO
FOR THE CDF AND D0 COLLABORATIONS

Universitá di Bologna

1 Introduction

The measurements of the mass of the W boson (M_W) and of the top quark (M_t) are important for three reasons: (i) these masses represent fundamental parameters of the Standard Model; (ii) they determine the coupling between the top quark and the Higgs boson, the coupling being proportional to M_t^2/M_W^2; and (iii) radiative corrections relate the masses of the W, top quark and the Higgs boson: an accurate measurement of M_W and M_t would provide a constraint on the Higgs mass (M_H).

We present here the measurements obtained by the CDF and D0 collaborations corresponding to the so-called Run I of data-taking (1992-95, ~ 100 pb^{-1} each) at the Tevatron ($p\bar{p}$ collisions, $\sqrt{s} = 1.8$ TeV). In addition we report on the improvements expected for these measurements in the current run (so-called Run IIa) which, having just started (March 2001), is expected to collect about 2 fb^{-1} by the year 2004.

2 The detectors: CDF and D0

CDF and D0 are the detectors which collect $p\bar{p}$ collisions at the Tevatron. A complete description of their Run I configuration can be found elsewhere[1, 2] and we summarize here the most relevant upgrades for Run II.

CDF has now a new tracking system with an upgraded silicon tracker (more coverage and three-dimensional), a new drift chamber, and the capability for a secondary vertex trigger. The forward parts of the calorimeters have been replaced while the muon system underwent only a minor improvement. A significant upgrade has been necessary in the trigger system to match the new run conditions.

D0 has become now a magnetic spectrometer with a new tracking system, including a silicon tracker for the identification of secondary vertices. The muon system has been improved and of course the trigger underwent a major upgrade.

3 W and top mass measurements

At the Tevatron W bosons are produced mainly via $qq' \to W$ and we consider the distinctive signatures containing a high-P_T lepton (e or μ) plus missing transverse energy. CDF and D0 have collected together about 130,000 of such events during Run I. The mass of the W boson depends on the electroweak parameters α, G_F and $\sin\theta_W$, but electroweak radiative corrections, due to top and Higgs loops, add contributions which depend quadratically on M_T and logarithmically on M_H. The mass of the W can be inferred from the reconstruction of the transverse mass, where the momentum of the neutrino is obtained balancing the lepton and the recoil *i.e.* the vector sum of the transverse momentum of all particles recoiling against the W. In the measurement procedure it is essential to model correctly the W production dynamics, the recoil and the detector response. Combining the electron and muon channels together, CDF obtains for Run I a W mass of 80.433 ± 0.079 GeV/c^2[3]. D0 considers instead only the electron channel, where the electron can be central or forward, and obtains $M_W = 80.482 \pm 0.091$ GeV/c^2[4]. The two measurements have been combined, considering a 25 MeV/c^2 common uncertainty, to give $M_W = 80.454 \pm 0.063$ GeV/c^2 as Tevatron average.

Top quarks are produced mainly in pairs via $q\bar{q} \to t\bar{t} \to W^+bW^-\bar{b}$. Final states are defined according to the W decays ($W \to \ell\nu$, $W \to qq'$) in terms of the number of high-P_T leptons (e or μ). We concentrate on the following channels: (i) double lepton (both statistics and backgrounds are low; $BR \approx 5\%$); (ii) single lepton (b-tag is necessary to reduce backgrounds; $BR \approx 30\%$); and (iii) all-hadronic (huge background, both b-tag and a tight kinematical selection are needed; $BR \approx 44\%$). CDF measures the top mass in all three channels obtaining an average value of 176.1 ± 6.6 GeV/c^2[5]. D0 measures the top mass using the single and double lepton channels, with an average of 172.1 ± 7.1 GeV/c^2[6]. The combination of the two measurements, including all uncertainty correlations, amounts to 174.3 ± 5.1 GeV/c^2.

If we compare in Fig. 1-left M_W and M_t we see that the constraint on M_H they introduce is quite loose.

4 Perspectives for the new run

The energy increase in the new run just started ($\sqrt{s} = 1.8 \to 2.0$ TeV) leads to a $30 - 40\%$ increase in cross sections. This and the $\times 20$ increase in integrated luminosity will lead to a large reduction in the statistical uncertainties. Regarding the systematic uncertainties on M_W, some of them will scale with the statistics (detector calibration), others will not, like QED corrections for electrons, QCD effects in the W/Z production, parton distribution function dependency. Extrapolating these uncertainties from Run I measurements is not simple, however we expect to reach a total uncertainty on M_W of about 30-40 MeV/c^2 (per experiment). For the top mass we expect, for instance, to calibrate the energy scale reconstructing the decays of the W's into two jets, and to evaluate the ISR/FSR dependency considering different jet multiplicities or double b-tags. We thus expect to improve the relative uncertainty on M_t from the current 3% to less than 2% (for experiment).

Considering the expected uncertainties on M_W and M_t, described above, the constraint on M_H becomes tighter, about 40%, as can be seen in Fig. 1-right.

5 Conclusions

Precise measurements of M_W and M_t are a fundamental test of the Standard Model and provide a constraint on M_H. We have reported here the Run I measurements of CDF and D0 for M_W and M_t. The uncertainties expected for Run IIa, which just started, should lead to a constraint of about 40% on M_H.

References

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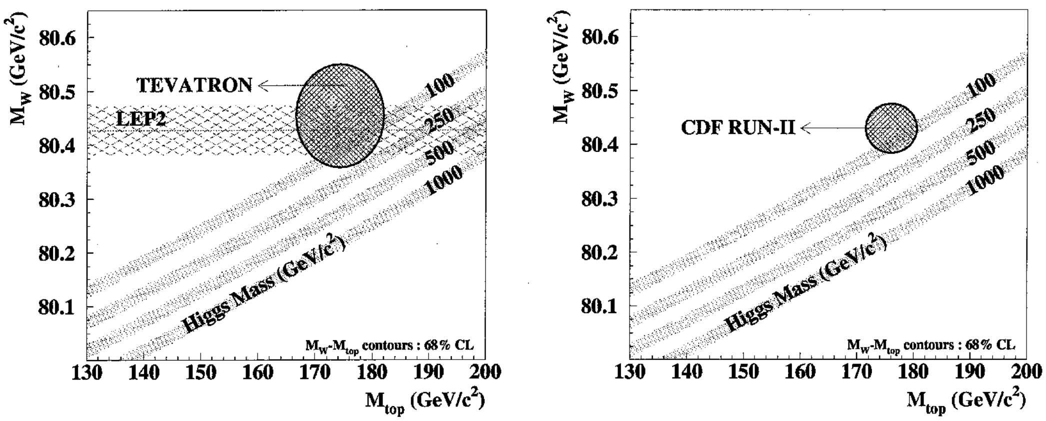

Figure 1: M_W vs M_t for Run I (left) and expected for Run IIa (right).